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ANALYSIS OF THE REUSE OF TIRES IN SYNTHETIC GRASS IN MANAUS FROM THE PERSPECTIVE OF THE REVERSE LOGISTICS PROCESS

Thielsse de Araújo Barbosa[1]
Cláudio Fernandes Tino[2]
Gilbert Breves Martins[3]
Luiz Henrique Claro Júnior[4]
Elisângela Leitão de Oliveira[5]
Márison Luiz Soares[6]
Daniel Nascimento-e-Silva[7]

ABSTRACT

Objective: This study aimed to analyze the reuse of tires by a company that produces synthetic grass in Manaus from the perspective of the reverse logistics process.

Methods: The scientific-technological method was used to build the theoretical architecture and generate empirical findings, consisting of four stages: a) elaboration of guiding research questions, b) data collection from the company's managers and employees through a script interview and an observation script, c) organization of data based on semantic analysis, so that each stage of the logistics process, its operations and purpose could be understood, and d) generation of answers to guiding questions, seeking to know what happens, how it happens and why it happens.

Results and discussion: The results showed that 1) the process of reusing the collected tires is made up of a few simple steps, 2) the reverse logistics planning procedures for the materials to be recycled include the objectives of the company and its suppliers, 3) the management procedures for the company's employees when executing the reverse logistics process take into account how much is known about the production and logistics process and 4) the control procedures for the objectives and goals to be achieved are based on indicators and metrics connected with the synergy of the team of collaborators.

Research implications: When the objectives and goals of organizations involved in the reverse logistics process are integrated, the possibility of success of the ventures increases considerably. Furthermore, it is necessary that the planning and execution of the reverse logistics process is built based on the stages of the management process.

Originality / Value: This study shows that innovation and creativity can reuse practically all materials that are usually discarded. Tires are a problem for almost all urban centers, but they have been transformed into exquisite synthetic grass for the most popular sport in Brazil, soccer. The company created other products aimed at home and building decoration.

[1] Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Manaus, Amazonas, Brazil.
E-mail: thielssebarbosa@gmail.com Orcid: https://orcid.org/0009-0000-5508-0202
[2] Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Manaus, Amazonas, Brazil.
E-mail: claudio.tino@ifam.edu.br Orcid: https://orcid.org/0009-0008-7250-0297
[3] Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Manaus, Amazonas, Brazil.
E-mail: gilbert.martins@ifam.edu.br Orcid: https://orcid.org/0009-0004-8844-2651
[4] Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Manaus, Amazonas, Brazil.
E-mail: luizclaro@ifam.edu.br Orcid: https://orcid.org/0000-0001-9249-6012
[5] Universidade do Estado do Amazonas, Manaus, Amazonas, Brazil.
E-mail: eloliveira@uea.edu.br Orcid: https://orcid.org/0000-0002-8252-1437
[6] Universidade Federal do Espírito Santo, Vitória, Espírito Santo, Brazil.
E-mail: marison.soares@ufes.br Orcid: https://orcid.org/0000-0003-3269-9365
[7] Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Manaus, Amazonas, Brazil.
E-mail: danielnss@gmail.com Orcid: https://orcid.org/0000-0001-9770-575X

Keywords: Reverse Logistics, Reverse Logistics Process, Tire Reuse, Environmental Management in the Amazon, Environmental Sustainability.

ANÁLISE DO REAPROVEITAMENTO DE PNEUS EM GRAMA SINTÉTICA NA CIDADE DE MANAUS SOB A ÓTICA DO PROCESSO LOGÍSTICO REVERSO

RESUMO

Objetivo: Este estudo teve como objetivo analisar o reaproveitamento de pneus por parte de uma empresa que produz grama sintética na cidade de Manaus sob a ótica do processo logístico reverso.

Métodos: Foi utilizado o método científico-tecnológico para construir a arquitetura teórica e gerar as descobertas empíricas, constituído em quatro etapas: a) elaboração de questões norteadoras de pesquisa, b) coleta de dados junto aos dirigentes e colaboradores da empresa através de um roteiro de entrevista e um roteiro de observação, c) organização dos dados com base na análise semântica, de maneira que se pudesse compreender cada etapa do processo logístico, suas operações e finalidade e d) geração das respostas às questões norteadoras, procurando-se saber o que acontece, como acontece e por que acontece.

Resultados e discussão: Os resultados mostraram que 1) o processo de reaproveitamento dos pneus coletados é composto por poucas e simples etapas, 2) os procedimentos de planejamento da logística reversa dos materiais a serem reciclados contemplam objetivos da empresa e de seus fornecedores, 3) os procedimentos de gestão dos colaboradores da empresa na execução do processo logístico reverso levam em consideração o quanto se conhece sobre o processo produtivo e logístico e 4) os procedimentos de controle dos objetivos e metas a serem alcançados são baseados em indicadores e métricas conectados com a sinergia da equipe de colaboradores.

Implicações da pesquisa: Quando os objetivos e metas das organizações envolvidas no processo logístico reverso estão integrados, a possibilidade de sucesso dos empreendimentos aumenta consideravelmente. Além disso, é necessário que o planejamento e execução do processo logístico reverso seja construído com base nas etapas do processo gerencial.

Originalidade / Valor: Este estudo mostra que a inovação e a criatividade conseguem reaproveitar praticamente todos os materiais que são costumeiramente descartados. Os pneus são um problema para quase todos os centros urbanos, mas que foram transformados em gramas sintéticas primorosas para a prática do esporte mais praticado no Brasil, o futebol. A empresa criou outros produtos voltados para decoração doméstica e predial.

Palavras-chaves: Logística Reversa, Processo Logístico Reverso, Reaproveitamento de Pneus, Gestão Ambiental na Amazônia, Sustentabilidade Ambientais.

1 INTRODUCTION

Reverse Logistics is related to actions carried out to return solid waste from industrial production or everyday use for reuse or to another environmentally suitable destination. It operates in all cargo movements within an organization, from the search for raw materials from suppliers to the distribution of produced goods between points of sale, commerce, and consumption itself. Through this tool, it becomes possible to reduce the impact of waste, giving companies and governments, for example, responsibility for the product's life cycle and raising awareness of their commitment to the environment.

Natural stocks are not infinite. It is, therefore, urgent that organizations, populations, and governments take responsibility for optimizing the use of resources, each with a specific focus. Populations need to change their behavior and attitudes towards consumption; governments need to create legal mechanisms so that the reuse of materials is effective, and organizations need to take responsibility for new ways of using discarded materials daily. In other words, it is necessary to understand that what is thrown away is not garbage but money in a harmful form of waste.

In the Amazonian scenario, the reuse of materials takes on a more acute contour, given the fragility of the region's biomes, despite the enormous diversity they contain. Some studies on reverse logistics in the area have already been developed, with significant contributions to science, such as those by Gomes et al. (2023), Cabral and Nascimento-e-Silva (2022), Bastos and Nascimento-e-Silva (2022), Martins and Nascimento-e-Silva (2021) and Santos et al. (2023). However, it is still in the early stages of understanding the challenges of the circular economy in the region with the world's largest tropical forest. It is in the context of these challenges that this research fits.

In this sense, this study aimed to analyze the reuse of tires by a company that produces synthetic grass in Manaus from the perspective of the reverse logistics process. To do this, it used the scientific-technological method developed by Nascimento-e-Silva (2012; 2020a; 2020b), which is characterized by the formulation of a research question, followed by data collection in scientific repositories (to create the theoretical architecture) and empirical data and information that, once organized, allow the desired answer to be visualized. This procedure was adopted to generate answers to four guiding questions, which structure both the theoretical architecture and the empirical findings.

2 REVERSE LOGISTICS: LITERATURE REVIEW

The literature survey showed that process is the most common equivalence term in reverse logistics (Almeida, 2019; Oliveira et al., 2020; Milani, 2019; Campos, 2019). The process is the continuous sequence of facts or operations that present a certain unity or are reproduced with a certain regularity; it is a sequential set of actions with a common objective. A process can have various purposes, such as creating, designing, transforming, and producing.

Reverse logistics is a process because it is made up of a series of steps so that it can achieve its intended objectives.

Reverse logistics is also considered an instrument, according to studies by Oliveira et al. (2020), Aquino (2019), Leal (2019), and Sbordone et al. (2018). An instrument is understood as an object or means used to perform a specific action or work, such as screwdrivers to tighten screws or pens to write. The function of the instrument is to make this action possible or to make measurements so that results can be produced. Reverse logistics is an instrument because it is a tool used to execute the return flow of the discarded final product to its place of origin so that it can be reused, remanufactured, or packaged in suitable locations.

Another term equivalent to reverse logistics in the literature was segment (Boer & Fernandes, 2012; Moreira, 2019). A segment is any divided part of a whole corresponding to a portion or portion of a whole. A portion has the essential role of organizing structurally so that it is more straightforward to see the composition of this whole when it is fragmented. In the same way, it is possible to see details that were not possible. Reverse logistics is a type of segment because it is part of a larger whole, which is the production system or environmental management system. As part of the production system, reverse logistics can be seen as a supplier of raw materials. In contrast, as part of environmental management, it is responsible for appropriately handling waste so as not to compromise natural resources or human and other health—living species.

The last equivalence term found in the literature review was channel, in the study by Alves (2020). A channel can be understood as a ligature that originates from one point to flow or transport a product to another point. It also designates the route traveled, such as water and river courses. The channel has the function of transport and navigation to a particular destination. From the point of view of reverse logistics, three channels can be found: the information flow, which starts with the customer and ends with the last-tier supplier; the production flow, which begins with the last-tier supplier and ends with the delivery of the product to the customer; and the financial flow, which starts with the customer, when they receive the requested product and ends with the last-tier supplier. Reverse logistics is a channel where all logistical aspects of goods occur, materializing regarding information, production, and money.

Equivalence terms represent the main approaches to reverse logistics. They have essential practical implications. For example, the approach as a process implies presenting its primary stages. Its points of origin, destination, and transport dynamics must be described if seen as a channel. In addition to approaches, every scientific phenomenon must be defined in its essential elements, characteristics that distinguish it from others, called attributes. The sum of the equivalence terms with the attributes allows us to understand what science knows about the phenomenon under study.

The most frequent attribute of reverse logistics is the cycle, as found in studies by Aquino (2019), Sbordone et al. (2018), Oliveira et al. (2020), Leal (2019), and Alves (2020). Generally, the life cycle of a product is thought of only in the productive sense. This cycle is a series of steps that involve the development of the product, from obtaining inputs and raw materials for its manufacture, the production process itself and consumption, and until its disposal. The life cycle model, for example, provides for the appropriate disposal of post-consumer products but focuses attention on the primary direction of the process, which begins with production and ends with consumption.

Another attribute of reverse logistics is solid waste (Aquino, 2019; Boer & Fernandes, 2012; Sbordone et al., 2018; Oliveira et al., 2020; Leal, 2019). This characteristic suggests that reverse logistics can reduce products that would otherwise be discarded, causing harmful effects such as environmental degradation. Reverse logistics allows solid waste to return to the reverse channel and can be reinserted into production processes. This procedure reduces ecological impacts, but the activities carried out in the reverse logistics process depend on the type of material and why it is in the system.

Another attribute that characterizes reverse logistics is actions (Oliveira et al., 2020; Leal, 2019; Sbordone et al., 2018; Aquino, 2019). This characteristic shows that practical actions, not just what appears in the speech, establish a reverse recycling channel, where the main waste generated finds a suitable destination to be recycled, which may or may not generate economic returns for the company but guarantees that there will be less environmental impact. Therefore, the actions attribute differs from pure activism, which is not considered integral to reverse logistics. It does not act directly on solid waste to incorporate it into reuse systems and adequate final packaging. These are the actions, for example, that make it possible to establish partnerships with cooperatives, suppliers, and customers, among others, that enable the implementation of channels for appropriate waste disposal.

Development was another attribute in the literature review as a characteristic of reverse logistics (Leal, 2019; Oliveira et al., 2020; Aquino, 2019; Sbordone et al., 2018). The development attribute is because environmental resources are finite. The implementation and development of reverse logistics becomes a way of developing the planet's sustainability since it is possible to reuse raw materials and reduce and improve consumption. The principle used in favor of sustainable development aims to be a business management model that considers environmental and social impacts, economic issues, and market competitiveness.

Another reverse logistics attribute was means (Oliveira et al., 2020; Leal, 2019; Sbordone et al., 2018; Aquino, 2019). The idea of means is correlated with ends, which is characterized by enabling the means for the reuse or final disposal, environmentally appropriate, of solid, liquid, and gaseous waste. In this sense, the organization needs to plan the receipt and forwarding of items to be reversed, establishing means of controlling the physical flow and logistical information in line with its business strategy. Often, the product can undergo improvements and be sold again, adding value and becoming a valuable means of achieving environmental and financial goals.

The last reverse logistics attribute identified in the literature was value, as seen in studies by Alves (2020), Delponte et al. (2020), and Milani (2019). What underlies value as an attribute is the intention to add economic, financial, and environmental value to the collected goods, mainly through their reuse, recycling, reuse or incineration and final packaging of these materials. Therefore, the reverse logistics system adds economic, ecological, and productive value to post-consumer goods because it creates conditions for the material to be reintegrated into the production cycle, replacing new raw materials and generating a new economy, the circular economy. The reuse system adds reuse value to post-consumer goods, and the incineration system, for example, adds economic value by transforming solid waste into electrical energy.

For this study, reverse logistics is defined as the process that aims to add value to production systems through actions carried out through a cycle, and that configures a new economy. This procedure incorporates solid waste into the production process through remanufacturing or recycling. The process encompasses the entire chain, from the producer to the consumer. As a cycle, the literature points out that reverse logistics is a recovery of the value of a good or product based on its new destination. It is a complex whole with a broad structure, which requires in-depth analysis to design the process with a high probability that its development will be correctly executed. In this way, reverse logistics can be understood in several ways. Still, all converge towards the same meaning and with a common objective: to guarantee the return of products from the beginning of the chain so that they can be transformed into new products and disposed of appropriately. The priority is always environmental management and reducing environmental impacts, followed by economic-financial performance. This can be achieved through specific steps and configuring a reverse logistics process.

2.1 REVERSE LOGISTICS STEPS

The study by Carmo et al. (2017) points to the collection of raw materials as the beginning of the reverse logistics process. This raw material can be a natural product or a transformed product that companies use as the basis in production to obtain a finished product. Next comes the inspection stage, examining the raw material. Then comes separation, in which the main product intended to be produced appears mixed with other by-products. The purchase is made when production is ordered, and the product is ready to be used. Finally, there is the return, which can occur when the product is unsuitable. The study by Campos (201p) also considers collection as the first stage, which is when the sample is carried out carefully so as not to interfere with the result. Then comes the selection, which seeks to separate the raw materials into those suitable and not suitable for processing, such as, for example, dividing them into compliant and non-compliant. After this comes the preparation of the raw material and then industrial recycling, which is the transformation of the waste into a new product ready to be used.

The study by Giese et al. (2021) presents the collection of raw materials as the first step. Next comes production, which is the process of carrying out something, aiming for a final product that meets a specific objective. Marketing is the next step, which seeks to put a product on sale or provide the conditions and means of distribution necessary for its sale. Consumption is the subsequent stage of using a product to satisfy a need. Then comes the disposal of waste, which are unused products, restarting the act of collecting, which is obtaining unused material. Triage comes next, as a separation that determines the priority of care and treatment. It continues with pre-processing and disassembly, which involves preparing, organizing, and structuring materials. Finally comes reprocessing and treatment, preparing the product for a new cycle. Araujo (2012) considers disassembly the first step, followed by cleaning and testing, to analyze whether the product has any defects. Next comes reassembly, when the product has been checked and will be sent to its appropriate customers.

For Lima et al. (2021), the first stage of reverse logistics is recovering lost material. Next comes recycling, to reduce the amount of waste resulting from recovered products; reuse, when the product is not transformed into another product and is reused in several other possible uses; or return, which is the return to the point where the product started, that is, back to the beginning of manufacturing the raw material. The study by Seppälä (2010) considers screening as the first step, which indicates the situation in which the product is found, whether it is compliant or not compliant for use. Next comes collection, followed by analysis and classification/situation of the product, to provide a position on whether the material can be used or what appropriate precautions should be taken to handle it.

For Alamassi (2014), the stages of reverse logistics begin with collection and transportation. Collection to collect and gather all the material and transport it to where the entire process will be carried out. Afterward, the material is inspected and separated to determine what can be used. The stages end with reprocessing when the material is transformed into a finished product and ready for consumption. The study by Kumar et al. (2015) presents the steps more objectively. The process begins with sorting, which collects the material or waste. They also separate and “sieve” all the material for reuse. The second stage is the collection, carried out by sorting agents, an action in which all the material is acquired to start reverse logistics. Afterward comes the classification, which determines whether the raw material collected can be used. Processing is the next step and has the function of modifying the waste or material so that it is suitable for use by the consumer. The authors end the cycle by discarding the final processed product, which means taking it to the consumer.

Kalogerakis (2015) presents a pattern that begins with the collection, which is searching for material to be used in the reverse logistics method. Next comes selection, which is the distinction of all the material collected, that is, what can be utilized. Then comes reprocessing, where all the material used will be changed to be ready for use. Then comes crushing, the fragmentation or division of each material already being reworked. The cycle ends with redistribution, which is the supply of the product to the consumer. In the study by Milano and Pugliesi (2014), the reverse logistics stages begin with the collection of materials that can be used. The second stage is packaging, in which the product is placed in a compartment to be definitively ready for use. The final step is shipping, which is getting the product to the customer. Azevedo (2015) presents a cycle that begins with the collection, which is the collection of material to be reused. Next comes transportation to move the material to the site for material processing. Then, the material is processed so that the customer can use it. The cycle ends with screening the reprocessed product to identify and correct errors, if necessary.

The study by Degra and Gobi (2015) stipulates the stages of reverse logistics, starting with collection, where all products and waste already used by a specific niche are collected. After collection comes the transportation of the material to the processing site. There, everything collected is decontaminated to remove the resins/dirt present in the material. The last stage is recycling, when the product returns to its original point and is ready to be consumed again. Finally, the study by Rosa et al. (2015) presents a cycle that begins with separation (before collection), when the raw material is divided for the next stage, which is the collection when the separated material is taken to a specific location for reprocessing. The next stage is the remanufacturing inspection, which is the manipulation and manufacture of the material to be ready for use, when it is analyzed to avoid failures and products with non-conformities are not passed.

The literature review established six steps for the reverse logistics process: collection, inspection, separation, classification, reprocessing, and redistribution. The first stage of the reverse logistics process is the collection, according to studies by Campos et al. (2018), Becker (2021), Nguyen (2021) and Piscitelli et al. (2020). From this stage, the reverse process begins when organizations such as cooperatives collect and receive the materials. Some collections are carried out door-to-door, through contracts with companies, or directly at landfills. The focus is on inorganic waste that can be recycled. The collection stage is necessary so that the materials can be sent to their recyclers, which, in addition to immediately reducing the environmental impact, allows us to move on to the second stage, inspection.

The second step is inspection (Seppala, 2010; Taheri-Tolgari & Mirzazadeh, 2021; Taheri & Mirzazadeh, 2022). This step requires attention, as it focuses on analyzing the physical and chemical characteristics of the collected material. The challenge of this stage is that there is no problem with the contamination of materials by harmful substances or that they cannot be reused for some reason. In relatively technological organizations, each material is directed to appropriate rooms using conveyors and according to its type so that it can be washed and discarded so that the final product is reused in the best possible way.

After inspection, the third step is carried out, which is separating the material (Carmo et al., 2017; Ip et al., 2018; Kowol & Matusiak, 2018; Rahman et al., 2023). This is considered a necessary step because it is through this that it is possible to start the production of new products. Separation takes place manually, automatically, or semi-automatically. The manual method is carried out through garbage collectors and is not the most appropriate way because, despite its low cost, it has a low production capacity; automatic separation can separate a much larger volume, in which the process is carried out quickly and without interruption for rest, but it is expensive, requires a large area for separation and is recommended for large metropolises; Semi-automatic separation involves human labor helping the machine to separate waste and has application in specific recycling.

The fourth step of reverse logistics is the classification of materials (Kumar et al., 2015; Wang et al., 2018; Rodrigo et al., 2024; Mirzaei et al., 2024; Hinkka et al., 2023). At this stage, classification is made according to the class of the material, which can be divided into at least two courses. The first corresponds to materials that can cause damage, such as corrosive, flammable, and toxic materials; the second covers waste that is not dangerous and does not pose risks, also subdivided into "non-inert" and "inert" subclasses, ranging from water to waste that does not undergo any alteration in the natural environment. This step is crucial because it facilitates the entire process of reusing recyclables safely.

The sixth step is the reprocessing of the material (Alamassi, 2017; König et al., 2024; Ding et al., 2023; Omosa et al., 2023). At this stage, all the material used will be reprocessed and transformed into a new material, which can be reused directly or used as raw material in production. Waste undergoes treatments and remodeling, with some chemicals and others added to the raw material of other materials. After being reprocessed, the resulting products can be sold again and reused in industries in a new format or even in the same way they were returned for recycling. These steps allow the transformation of material that would otherwise be discarded in nature into raw material for new products or simply for direct reuse.

The sixth and final step is redistributing the material (Araújo et al., 2012; Schleier & Walther, 2024; Tan et al., 2023; Han et al., 2023; Panghal et al., 2023). It is from a distribution that the product can return in its own restored old form or as a new product. Distribution can be carried out directly, which is when it is designed for large volumes of the same product or a few companies, such as, for example, soft drinks that use glass bottles. The search for the best distribution method involves conducting in-depth studies, mainly to find the appropriate demand for the products made with the collected discarded materials. The higher the quality of the material the company distributes, the greater the value of its image in the market, which almost always results in increased revenue and contribution to environmental sustainability.

3 RESEARCH METHODOLOGY

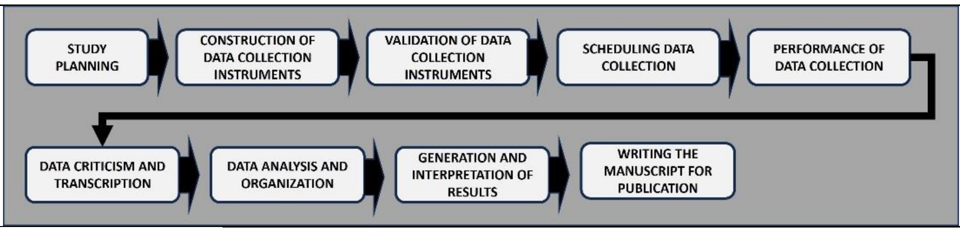
This study analyzed the reuse of tires by a company that produces synthetic grass in Manaus from the perspective of the reverse logistics process. To this end, five guiding research questions were formulated: 1) What is the process for reusing collected tires? 2) What are the reverse logistics planning procedures for materials to be recycled? 3) What are the management procedures for the company's employees when carrying out the reverse logistics process? 4) What are the procedures for controlling the objectives and goals? This methodological section is organized to present the answers obtained to these questions.

3.1 STUDY DESIGN

The research methodology followed nine stages, by the guidelines of Nascimento-e-Silva (2020; 2021a; 2021b; 2021c; 2023). The first stage involved planning the study, defining the objectives, guiding questions and response criteria, and fieldwork procedures. In the second stage, data collection instruments were created: an interview guide and an observation guide. In the third stage, the instruments were tested and validated to ensure that the desired data would be collected by the criteria for answering the research questions defined in the study plan. In the fourth stage, interviews and observations of the company's reverse logistics were scheduled, and the agenda was fulfilled in the fifth stage, as shown in the flowchart in Figure 1.

Figure 1

Study design.



Source: Prepared by the authors.

After being collected, in the sixth stage, the data were criticized based on the response criteria defined in the study planning, followed by transcription into a word processor. Each response was fragmented into essential components in the seventh stage, configuring the data analysis. It was then organized using semantic analysis techniques since all data was collected in text form. In the eighth stage, results were generated in terms of answers to each guiding question, which were then compared with the theoretical architecture of the study. The study was completed in the ninth stage, with the writing of the manuscript for publication.

3.2 RESEARCH SUBJECTS

The organization researched has Mr. A (Isaias Moraes) and Mr. B (Alexandre Moraes) as its owners. Employees X (Magno Chagas) and Y (Edivaldo Lima) represented the team responsible for reverse logistics. Mr. A was the one who led us through the entire process of introducing the company, staff, and reverse logistics processes. The partners also provided in-depth answers on future investment issues, dealings with the operational team, and all administrative activities. They also reported on the difficulties encountered in the day-to-day process, such as the issue of transporting the product to the customer and the challenges faced during the assembly of the fields. The youngest employee in the company has a year and a half of experience and is considered by our research team to be knowledgeable about all processes and in control of everything that is carried out in reverse logistics. On the other hand, the interviewed partners remained present throughout the data collection period. They showed us a horizontal view of how close the administrative managers and all the employees involved were throughout the process.

3.3 DATA COLLECTION INSTRUMENTS

We carried out a semi-structured interview with the support of a question guide. We personalized the questions, focusing them on understanding the company's activities focused on reverse logistics, the infrastructure used, and the performance of its collaborative framework, as we identify that it is a family business. Through an observation script, we mapped all stages of tire reverse logistics, and the raw material was transformed into the main product produced by the organization. Through these two instruments, we obtained an adequate understanding to generate answers to all the research guiding questions and the administrative challenges in obtaining the raw material, which comes from another state in Brazil.

The instruments allowed us to identify the main difficulties affecting the raw material logistics chain, price negotiation, transportation, and weather conditions. These different approaches were necessary to understand how the company contributes to the local circular economy and the potential for developing the tire as a significant investment for the state of Amazonas. The data and information obtained via observation were validated by the data and information collected from the owners and collaborative framework and vice versa.

3.4 DATA COLLECTION STRATEGY

Data were collected on days and times previously scheduled with the company's management. The scripts were previously approved when they were emailed to managers, who used them to organize the observation script internally and externally and collect quantitative and qualitative information on essential aspects of the reverse logistics practiced by the company. Managers and collaborators were the generators of data and information, taking turns responding and complementing the responses provided by others. The same collection procedure was carried out by observing reverse logistics practice, using a field notebook to make the necessary records. Photographing the production process and organizing the company's physical space was allowed.

3.5 DATA ORGANIZATION AND ANALYSIS TECHNIQUES

The data was transcribed into a word processor, at which point it was criticized. The criticisms aimed to transcribe each answer to each guiding question in a way that allowed the logic and practice of reverse logistics to be understood. For example, for the question “What is the process of reusing collected tires?” the transcription sought to cover all the steps, from the first to the last, so that they could all be clear and understandable to the researchers. The interviewees' answers were always mixed with the data and information collected via observation and photographs to compose this logic.

Data organization was done with the help of an electronic spreadsheet. The organization of responses was based on the triad: what, how, and why. In the case of the guiding question “What is the process for reusing collected tires?” we sought to understand a) what was done at each stage of the process, b) how this stage was carried out, and c) why the company proceeded in that way. The same procedure was used for all other research questions. Nascimento-e-Silva (2023) recommends this procedure to have an in-depth understanding of this type of research question, classified as procedural.

3.6 TECHNIQUES FOR GENERATING AND INTERPRETING RESULTS

The results were generated from the procedural organization of the data obtained. All guiding questions seek to understand the processes practiced by the company in carrying out reverse logistics. A result was considered achieved when all process stages were known (Nascimento-e-Silva, 2023). The reasons for their procedures were explained, and how they were carried out were described. This procedure was necessary to compare the responses obtained with the theoretical architecture of the study and, thus, proceed with interpreting the results achieved.

The results were interpreted by comparing the empirical findings with the architecture in the literature review. The great challenge of interpretation is finding an answer to the question, “What does this mean?”. For example, it was discovered that the company's reverse logistics planning is done daily, weekly, and monthly. What does that mean? Comparison with the literature showed us that layered planning is necessary to integrate the organization's objectives and goals with its suppliers. Interpreting the results, therefore, means coupling local empirical findings with theory, which always has a universal scope.

4 RESULTS AND DISCUSSION

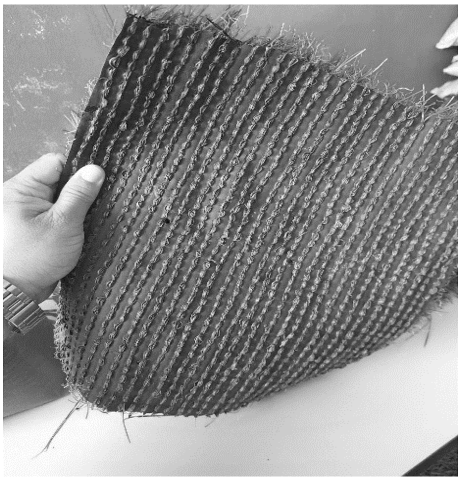
The company that is the subject of this investigation works specifically with the production, installation, and repair of synthetic lawns supplied to the entire city of Manaus, providing the structure for the various football fields and arenas spread throughout the region. The organization practices reverse logistics by paying close attention to the details of its production process so that it always complies with sustainable principles, respecting and not harming the environment. Managers consider that sustainable economic principles allow the company to obtain economic and financial gains. The more excellent and better the practice of a sustainable economy, the better its economic-financial performance tends to be.

4.1 THE REUSE PROCESS

The owner informed us that the manufacture of synthetic grass is like the tufting techniques in carpets, as shown in Figure 2. The first step in the production process is mixing the ingredients in a funnel. Then, the dye and chemicals are added to give the traditional green and, in addition, protect the final product from ultraviolet rays. The managers explain that the batch is thoroughly mixed. These synthetic grass production materials are mixed numerous times until they appear pasty. The pasty liquid is then inserted and heated in an extrusion machine, which ensures the modeling of individual strands, from which long, thin strands of the material emerge.

Figure 2

Synthetic Carpet.



Source: photograph captured by the authors.

The production process continues with the yarns being placed and taken to a sizeable tufting machine, where they are struck by needles and sewn. They are then placed in cutting machines and spun into loose ropes to be wound onto bobbins. These strings are pulled, straightened, and woven into yarn to be wound onto bobbins and heated. The threads pass onto a spool and are fed through a tube carrying a tufting needle. The needle pierces and loosens the primary support of the grass cover and pushes it into a loop. There is a flat hook that grabs and releases the grass fiber. The material is then rolled over a dispenser, which spreads a latex coating on the underside of the grass. The lawn is then placed under heat lamps. After heating, the grass is taken to a machine, removing all the tufts above its predetermined surface. The process is repeated daily to make synthetic grass.

The study by Fang et al. (2023) shows that approximately half of the world's tire production will be discarded into the environment without treatment. Environmental pollution is a sad reality (Rozhenko et al., 2023; Kumar & Sahoo, 2021). The production of synthetic grass has become an exciting way of reusing this material without the high costs of other alternatives, such as pyrolysis (Padha et al., 2024; Mousavi et al., 2024; Khanzada et al ., 2024). The organization under analysis managed to develop a very efficient reverse logistics scheme because it transfers challenging aspects to its raw material suppliers, which results in the delivery of materials practically ready to enter directly into the production line of its products.

4.2 PLANNING THE REVERSE LOGISTICS OF MATERIALS TO BE RECYCLED

The reverse logistics practiced in the company is planned. Planning aims to collect as many raw materials as possible but with temporally specified objectives. Every day, the challenge is obtaining as many recycled materials as possible. Every week, the aim is to reprocess the rubber to transform it into synthetic grass. Every month, the objective is to reduce environmental damage, measured through a) the effectiveness of reverse logistics execution and b) reduction in production costs using rubber as a raw material for producing synthetic lawns.

For its objectives and goals to be achieved and thus achieve effectiveness, the company collects the raw materials used in its production process. An example of this procedure is the collection of rubber in scrapyards, configured as suppliers with the highest quality materials compared to the alternatives available in the city. This material is inspected and sometimes undergoes some preparation to be placed in production, transforming it into synthetic grass. Synthetic grass is suitable for sports or decorative use; what changes in these applications are the bases, single or double, depending on their usefulness, as some require high intensity. There is also the possibility of superficial sand filling in the product when necessary. In the final phase of the synthetic grass manufacturing process, the product is rolled into specific equipment and immediately packaged in plastic blankets, which guarantee the quality, durability, and guarantee of the product for storage. Grass is sold in square meter pieces. For the customer to know how much they need to invest in the project, the ideal is to measure the area they want to apply and place the order per square meter.

These results indicate that the organization under analysis integrated its production system with its suppliers' operations in its planning process. In practice, business and environmental aspects are connected, which increases the chances of sustainable success for this type of enterprise (Helms & Hervani, 2024; Xiaoping & Meiyan, 2023; Resti et al., 2023). Planning involves defining the intended objective and its breakdown in quantity and time (goals). Each stage needs to be meticulously designed when planning the production process to minimize the possibility of failures and resulting nonconformities. When making daily, weekly, and monthly schedules is necessary.

4.3 PEOPLE MANAGEMENT IN REVERSE LOGISTICS

Labor for this type of industry is scarce. Finding formally trained professionals with experience collecting recycled materials and producing and applying the product is difficult. This is because professionals working in these segments need specific knowledge about all the processes that involve product recycling, from its reuse to the final application. The company has a favorable environment for developing its collaborative framework, applying training, establishing infrastructure improvements, and an incentive program with bonuses for reaching seasonal targets. The manager and owner demonstrated knowledge about the personality and taste of each of his employees to provide a work environment that promotes employee satisfaction and motivation.

Despite all the efforts of its management team, those interviewed stated that some conflicts do occur. The reason is that a small portion of employees still need to have the environmental sustainability mentality that this type of enterprise requires, compared to the majority, who are more concerned than others about the environment. An example of conflicts collected was about the issue of displaying goods. Although they are qualified to withstand any external environment, some employees who store merchandise say they do not have enough space to store all the material in covered stock, offering less care when stored in any other temporary location. The employees responsible for supplies, negotiation, shipping, and acquiring goods and raw materials to perform customer service signal the need for more efficient and adequate storage, accessible from mixtures, dirt, and insects. These two distinct views generate conflicts that sometimes require the intervention of the company's management to resolve them.

The owner interviewed assured that the solution to this conflict in the example mentioned is already under development, with a deadline for complete resolution in approximately sixty days. He showed an area where construction is underway that can supply all the desired infrastructure for better handling, storage, and execution of services for its entire production team. This new area will include acquiring goods resulting from an investment in the area and purchasing new machinery for application in the tire reverse logistics process on a regional basis. He states that when acquired, it will be the first company in Manaus to guarantee the delivery of materials from the state itself. Applying some of these raw materials in the design process of synthetic fields is only possible through acquiring these resources from other states. This way, in addition to offering a better and more extensive stock of all products, it will have its production, ensuring it meets state and regional demand in creating new synthetic lawns.

People are the main asset of every organization (Matteis et al., 2023; Mitterer & Mitterer, 2023; Pharris & Perez-Mira, 2023). It is impossible to separate owners, managers and subordinates, bosses and employees, or owners and workers when talking about people. People are all human beings who are part of an organization, regardless of their contribution to the enterprise's success. In organizations whose products are intrinsically focused on sustainability, as is the case of the organization under analysis, the people challenge is much greater than those focused exclusively on an organizational aspect. This means that obtaining only financial advantages, even if they require several efforts to satisfy customers, is a less complex purpose than another that aims to achieve financial, economic, social, and environmental success, for example.

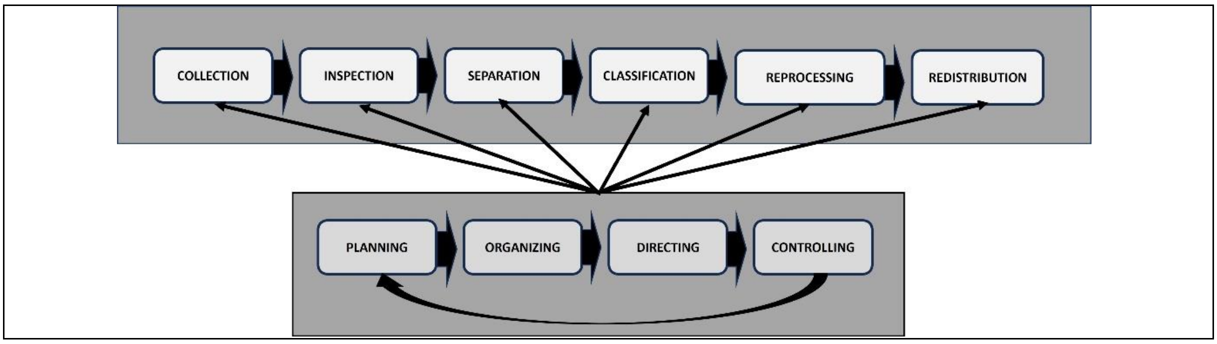
4.4 THE CONTROL PROCESS IN REVERSE LOGISTICS

The company's reverse logistics objectives and goals are controlled through indicators and metrics determining the team's synergy. These procedures show what teams must deliver and how to deliver each delivery. There is, therefore, a performance control system and numbers to achieve objectives and targets. Deadlines for completing each objective and goal are also established. The company controls its processes and the stages of its production process based on projects. The project contains what each client requests and the services to be performed. From the order, the company collects the necessary information to prepare the project, where every detail of each service is foreseen and planned so that the company and the client always have control of the internal production system in their hands. Finally, the company controls the quality of its reverse logistics by standardizing the services provided. Quantitative and qualitative standardization allows possible flaws that compromise the quality of the product and services to be identified. This procedure improves services, constantly adapting its methods to the details and services contained in the customer's requirements. This way of proceeding is already part of the company’s culture.

Control is the effort to ensure that the execution of the plan does not deviate from the intended objectives and goals so that every plan has its control scheme, as can be seen in the studies by Wang et al. (2024), Jaafar et al. (2024), Raamets et al. (2024) and Xu (2024). Planning logistical stages and their respective activities requires control schemes that prevent the quantitative and qualitative aspects of organizational actions from being achieved. This means, for example, that every reverse logistics process needs to be supported by some management process specifically designed for it so that logistics and management must be integrated and complementary.

Figure 2

Reverse logistics process and management process.



Source: Prepared by the authors.

As shown in Figure 3, the material to be reused needs to be collected, inspected, separated, and classified so that it can be reprocessed and then distributed to its customers. Each stage needs to use the management process for consonance between environmental and business (economic-financial) objectives. This means, for example, that it is necessary to plan, organize, direct, and control the collection of material so that the objectives and goals of this stage can be achieved and, thus, increase the chances that the inspection stage can also be successful in its objectives and goals. This same concern must guide all phases of the reverse logistics process to increase your chances of economic-financial success and influential contribution to sustainability.

5 CONCLUSION

This study analyzed the reverse logistics of transforming tires into synthetic grass by a company operating in Manaus. The results showed that the process of reusing the collected tires is made up of a few simple steps: the planning procedures for the reverse logistics of the materials to be recycled include the objectives of the company and its suppliers, the management procedures for the company's employees in the execution of the reverse logistics process take into account how much is known about the production and logistics process and the methods for controlling the objectives and goals to be achieved are based on indicators and metrics connected with the synergy of the team of collaborators.

The study found that reverse logistics deals with the movement and transportation of material to be reused from the disposal of consumption throughout the production process and back for a new consumption cycle. This system requires adequate means to collect and provide post-sale or post-consumer disposal of what is discarded for reprocessing or correct waste disposal. It was noted that the importance of applying reverse logistics for business logistics operations is the study and management of discards and the reintegration of by-products from the production process.

Unfortunately, much of what is discarded in Manaus is still not reused. Our study was able to determine some aspects so that it is possible to obtain the economic return or social and ecological values, such as creating incentive policies so that there is guidance and correct disposal of materials, creating collection routes to create favorable conditions for reuse and establishing partnerships between the main actors involved, such as citizens, organizations, and governments. They need to understand that reverse logistics brings great benefits by lowering costs, improving customer services, and maintaining the stock of natural resources. The company assumes responsibility for what it produces and gives the destination to the products it generates. This contributes to the common good and reduces the environmental impact it causes.

REFERENCES

Alamassi, F. N. M. (2014). *Reverse logistics network design with uncertainty*. Unpublished master thesis, Yildiz Technical University, Turkey.

Almeida, A. V. C. (2019). *Diagnóstico de reutilização e reciclagem de resíduos sólidos de construção civil pelas cooperativas de reciclagem no município de Belém-PA.* Unpublished master thesis, Universidade Federal do Pará, Brazil.

Alves, H. et al. (2020). Logística reversa de pós-venda aplicada ao e-commerce. *In Anais do XI FATECLOG.* Bragança Paulista, Brazil, October 23th – 24th.

Aquino, Í. R. B. (2019). *Proposição de um modelo matemático para localização de pontos de coleta de resíduos elétricos e eletroeletrônicos na cidade de Caruaru-PE*. Unpublished master thesis, Universidade Federal de Pernambuco, Brazil.

Araujo, F. S. et al. (2012). Estratégias de ecodesign aplicadas às atividades da logística reversa. *REBRAE*, 5(1), 105-116. https://doi.org/10.7213/rebrae.6073.

Azevedo, J. L. (2015). A economia circular aplicada no Brasil: uma análise a partir dos instrumentos legais existentes para a logística reversa. *In XI Congresso Nacional de Excelência em gestão, Niterói*, Brazil, August 13th to 14th.

Bastos, J. V. P., & Nascimento-e-Silva, D. (2022). Difficulties in performing selective waste collection in the city of Manaus, Brazil. *Research, Society and Development*, 11(16), 1-18. http://dx.doi.org/10.33448/rsd-v11i16.37808.

Becker, T. (2021). *Environmental sustainability and reshoring in the automotive industry: a multiple cases study*. Unpublished Ph.D. thesis. Sheffield Hallam University, United Kingdom.

Boer, N., & Fernandes, B. O. (2012). Descarte de medicamentos: um modelo de logística reversa. *In Congresso Internacional Responsabilidade e Reciprocidade*. Porto Alegre, Brazil, November 4th to 5th

Cabral, L. S., & Nascimento-e-Silva, D. (2022). Analysis of the challenges of a private cardboard recycling company to fulfill its mission in the city of Manaus, Amazonas. *Research, Society and Development*, 11(15), 1-16. http://dx.doi.org/10.33448/rsd-v11i15.37116.

Campos, A. (2019). *Produção de tijolos de solo-cimento com materiais de descarte: proposta com viés de sustentabilidade*. Unpublished Ph.D. thesis, Universidade Metodista de Piracicaba, Brazil.

Campos, C. A. M. et al. (2018). Efluentes e resíduos sólidos oriundos da produção offset na divisão gráfica da UFRJ. *Práticas em Gestão Pública Universitária*, 2(2), 83-99.

Carmo, B. S., Mascarenhas, M. P., & Marçal, S. (2017). A logística reversa. *Libertas: Revista de Ciênciais Sociais Aplicadas*, 7(2), 211-220.

Degra, A., & Gobi, E. (2015). Logística reversa. *Lume Arquitetura*, 73, 20-25.

Delponte, A. A. et al. (2020). Responsabilidade ambiental nas empresas: aplicabilidade da Lei 12.305/2010 sob o viés da logística reversa. *Revista Gestão & Sustentabilidade Ambiental*, 9(1), 396-420. https://doi.org/10.19177/rgsa.v9e12020396-420.

Ding, L., Wang, T., & Chan, P. W. (2023). Forward and reverse logistics for circular economy in construction: A systematic literature review. *Journal of Cleaner Production*, *388*, 1-14. https://doi.org/10.1016/j.jclepro.2023.135981.

Fang, H., Hou, Z., Shan, L., Cai, X., & Xin, Z. (2023). Influence of pyrolytic carbon black derived from waste tires at varied temperatures within an industrial continuous rotating moving bed system. *Polymers*, *15*(16), 3460. https://doi.org/10.3390/polym15163460.

Giese, E. C., Xavier, L. H., Ottoni, M., & Araujo, R. A. (Orgs.). (2021). *Cooperativas e a gestão de resíduos eletroeletrônicos*. Rio de Janeiro: CETEM/MCTI.

Gomes, A. S., Simão, F. N., Silva, R. F., & Nascimento-e-Silva, D. (2023). The difficulties of solid waste collectors carrying out selective collection in the city of Manaus, Brazil. *Recima 21 – Revista Científica Multidisciplinar*, 4(3), 1-20. https://doi.org/10.47820/recima21.v4i3.2881.

Han, Y., Zhang, M., Nan, P., Cao, J., Huang, Q., Ye, X., & He, Z. (2023). Two-stage heuristic algorithm for vehicle-drone collaborative delivery and pickup based on medical supplies resource allocation. *Journal of King Saud University-Computer and Information Sciences*, *35*(10), 1–19. https://doi.org/10.1016/j.jksuci.2023.101811.

Helms, M., & Hervani, A. (2024). Reverse logistics within the supply chain. In *The Palgrave handbook of supply chain management*. Cham: Springer International Publishing.

Hinkka, V., Aminoff, A., Palmgren, R., Heikkilä, P., & Harlin, A. (2023). Investigating postponement and speculation approaches to the end-of-life textile supply chain. *Journal of cleaner production*, *422*, 138431. https://doi.org/10.1016/j.jclepro.2023.138431.

Ip, K., Testa, M., Raymond, A., Graves, S. C., & Gutowski, T. (2018). Performance evaluation of material separation in a material recovery facility using a network flow model. *Resources, Conservation and Recycling*, *131*, 192-205. https://doi.org/10.1016/j.resconrec.2017.11.021.

Jaafar, H. A. et al. (2024). MR. CAP: Multi-robot joint control and planning for object transport. *IEEE Control Systems Letters*., 8, 139-144. https://doi.org/10.1109/LCSYS.2024.3349989.

Kalogerakis, K. et al. (2015). Closed-loop supply chains for cradle-to-cradle products. In Kersten, W. B., & Ringle, C. M. T. (eds.) Sustainability in logistics and supply chain management: new designs and strategies. *Proceedings of the Hamburg International Conference of Logistics (HICL)*. Berlin: epubli GmbH.

Khanzada, N. K., Al-Juboori, R. A., Khatri, M., Ahmed, F. E., Ibrahim, Y., & Hilal, N. (2024). Sustainability in membrane technology: membrane recycling and fabrication using recycled waste. *Membranes*, *14*(2), 52. https://doi.org/10.3390/membranes14020052.

König, K., Mathieu, J., & Vielhaber, M. (2024). Resource conservation by means of lightweight design and design for circularity: A concept for decision making in the early phase of product development. *Resources, Conservation and Recycling*, *201*, 1-15. https://doi.org/10.1016/j.resconrec.2023.107331.

Kowol, D., & Matusiak, P. (2018). Technology of fine coal grains recovery from the mining waste deposits. In *IOP Conference Series: Materials Science and Engineering*, 427(1), 012025. https://doi.org/10.1088/1757-899X/427/1/012025.

Kumar, S., & Sahoo, S. K. (2021). Eco-sustainability of the textile production: waste recovery and current recycling in the composites world. *Dogo Rangsang Research Journal*, 14(4), 1916-19-40.

Kumar, V. V. et al. Economical impact of RFID implementation in remanufacturing: a Chaos-based interactive artificial bee colony approach. *Journal of Intelligent Manufacturing*, 26(4), 815-830, 2015. https://doi.org/10.1007/s10845-013-0836-9.

Leal, D. A. (2019). *Mapeamento do processo de gerenciamento dos resíduos da construção civil em Fortaleza*. Unpublished master thesis, Universidade Federal do Ceará, Brazil.

Lima, L. N. S., Salum, M. I. F,. & Cruz, C. A. B. (2021). Logística reversa na feira livre: um estudo de caso no munícipio de Carira/SE. *Revista Científica da Ajes*, 10(20), 49-60.

Martins, G. B., & Nascimento-e-Silva, D. (2021). Reuse of electronic devices. In Queiroz Neto, J. P., & Prokky, C. (eds.). *Lapassion Manaus: An innovative educational project for Amazon sustainability*. Belo Horizonte: Poisson.

Matteis, J. et al. (2023). Business continuity management and organizational resilience: A small and medium enterprises (SMEs) perspective. *Journal of Contingencies and Crisis Management*, 31(4), 670-682. https://doi.org/10.1111/1468-5973.12470.

Milani, M. (2019). *As experiências laborais de catadores no município de Feliz-RS: contribuições educativas para a logística reserva informal de resíduos sólidos urbanos*. Unpublished Ph.D. thesis, Universidade do Vale do Rio dos Sinos, Brazil.

Milano, C., & Pugliesi, E. (2014). Reverse logistics: studies and complementation. *Proceedings of the Fifth International Symposium on Energy from Biomass and Waste San Servolo 2014*, Venice, Italy, November 17th to 20th.

Mirzaei, A., Azarm, H., & Noshad, M. (2024). Designing sustainability comprehensive indicator for the food supply chain under climate change: A systematic literature review. *Ecological Indicators*, *159*, 111722. https://doi.org/10.1016/j.ecolind.2024.111722.

Mitterer, D. M., & Mitterer, H. E. (2023). The mediating effect of trust on psychological safety and job satisfaction. *Journal of Behavioral and Applied Management*, *23*(1), 29-41.

Moreira, C. D. C. (2019). Análise de viabilidade da aplicação de logística reversa na gestão sustentável de embalagens de cimento pós-consumo. Unpublished master thesis, Universidade Federal Fluminense, Niterói, Brazil.

Mousavi, M., Kowsari, E., Gheibi, M., Cheshmeh, Z. A., Teymoorian, T., & Ramakrishna, S. (2024). Assessing bioplastics' economic, commercial, political, and energy potential with circular economy modeling: A sustainable solution to plastic waste management. *Materials Circular Economy*, *6*(1), 1-36. https://doi.org/10.1007/s42824-023-00098-2.

Nascimento-e-Silva, D. (2020). *Manual do método científico-tecnológico: edição sintética*. Manaus: DNS Editor.

Nascimento-e-Silva, D. (2021a). *Handbook of the scientific-technological method: synthetic edition*. Manaus: DNS Editor.

Nascimento-e-Silva, D. (2021b). *O método científico-tecnológico: fundamentos*. Manaus: DNS Editor.

Nascimento-e-Silva, D. (2021c). *O método científico-tecnológico: questões de pesquisa*. Manaus: DNS Editor.

Nascimento-e-Silva, D. (2023). *O método científico-tecnológico: coleta de dados*. Manaus: DNS Editor.

Nguyen, L. A. (2021). Management innovation: A critical review. *Journal of Organisational Studies & Innovation*, *8*(1), 31-51. https://doi.org/10.51659/josi.19.118.

Oliveira, E. F. et al. (2020). Logistica reversa: importância econômica, social e ambiental. *Brazilian Journal of Animal and Environmental Research*, 3(4), 4325-4337. https://doi.org/10.34188/bjaerv3n4-135.

Oliveira, E., & Banaszeski, C. L. (2021). A logística reversa no descarte de medicamentos. *Saúde e Desenvolvimento*, 10(18), 21-37.

Omosa, G. B., Numfor, S. A., & Kosacka-Olejnik, M. (2023). Modeling a reverse logistics supply chain for end-of-life vehicle recycling risk management: A fuzzy risk analysis approach. *Sustainability*, *15*(3), 1-19. https://doi.org/10.3390/su15032142.

Padha, B., Verma, S., Ahmed, A., Chavhan, M. P., Mahajan, P., & Arya, S. (2024). From trash to treasure: crafting electrochemical supercapacitors with recycled waste materials. *Progress in Energy*, *6*(1), 012005. https://doi.org/10.1088/2516-1083/ad139c.

Panghal, A., P, A., Vern, P., & Mor, R. S. (2023). Adoption barriers to green logistics in the Indian food industry: A circular economy perspective. *International Social Science Journal*, 1-20. https://doi.org/10.1111/issj.12466.

Pharris, L., & Perez-Mira, B. (2023). Preventing social engineering: a phenomenological inquiry. *Information & Computer Security*, *31*(1), 1-31. https://doi.org/10.1108/ICS-09-2021-0137.

Piscitelli, G. et al. (2020). Circular economy models in the industry 4.0 era: A review of the last decade. *Procedia Manufacturing*, *42*, 227-234. https://doi.org/10.1016/j.promfg.2020.02.074.

Raamets, T., Majak, J., Karjust, K., Mahmood, K., & Hermaste, A. (2024). Development of process optimization model for autonomous mobile robot used in production logistics. In *AIP Conference Proceedings*, 2989(1), 020008. https://doi.org/10.1063/5.0189299.

Rahman, M. M. et al. (2023). A decision support tool for e-waste recycling operations using the hen-and-chicks bio-inspired optimization metaheuristic. *Decision Analytics Journal*, *7*, 1-15. https://doi.org/10.1016/j.dajour.2023.100216.

Resti, L. I., Mawengkang, H., & Rosmaini, E. (2023). Mathematical model for vehicle routing and scheduling with forward and reverse logistics. *Sinkron: jurnal dan penelitian teknik informatika*, *8*(3), 1536-1543. https://doi.org/10.33395/sinkron.v8i3.12599.

Rodrigo, N., Omrany, H., Chang, R., & Zuo, J. (2024). Leveraging digital technologies for circular economy in construction industry: A way forward. *Smart and Sustainable Built Environment*, *13*(1), 85-116. https://doi.org/10.1108/SASBE-05-2023-0111.

Rosa, F. R., Matias, J. S., & Junho, B. O. (2016). A Importância da logística reversa no campo industrial: aplicação no reprocessamento do alumínio. In *Anais do III & IV Congresso Científico da Produção da Universidade do Vale do Sapucaí* 2014/2015. Pouso Alegre, Brazil.

Rozhenko, O., Iurchenko, M., & Juscius, V. (2023). The Innovative Strategy of the Business Development Based on the Waste Tire Recycling in the Republic of Lithuania. *Management Systems in Production Engineering*, *31*(2), 162-171. https://doi.org/10.2478/mspe-2023-0018.

Santos, T. A. M. et al. (2023). Analysis of difficulties in solid waste collection from the point of view of a collector in the city of Manaus, Brazil. *IOSR Journal of Business and Management (IOSR-JBM)*, 25(12), 33-44. https://doi.org/10.9790/487X-2512083344.

Sbordone, M. A. et al. (2022). Uma abordagem baseada em capacidade: reinventar relacionamentos viáveis com pessoas e materiais. *Modapalavra e-periódico*, 15(35), 18-48. https://doi.org/10.5965/1982615x15352022018.

Schleier, J., & Walther, G. (2024). Strategic network design for recycling of EPS insulation material–insights from a German case study. *International Journal of Production Research*, 1-27. https://doi.org/10.1080/00207543.2024.2302041.

Seppälä, S. (2010). *Developing reverse logistics: case: developing return and reuse process in case organization*. Unpublished master thesis, Lahti University of Applied Sciences, Finland.

Silva, M. M., Coneglian, R. C., & Ferreira, M. A. (2020). Análise da oferta de resíduos sólidos urbanos para dimensionamento de estoque de segurança para um conjunto de cooperativas de coleta. *In X Congresso Brasileiro de Engenharia de Produção*, Online, December 2nd to 4th.

Taheri, J., & Mirzazadeh, A. (2022). Optimization of inventory system with defects, rework failure, and two types of errors under crisp and fuzzy approach. *Journal of Industrial and Management Optimization*, *18*(4), 2289-2318. https://doi.org/10.3934/jimo.2021068.

Taheri-Tolgari, J., & Mirzazadeh, A. (2021). Multi-item single-source production quantity model for imperfect items with rework failure, inspection errors, scraps, and backordering. *International Journal of Industrial and Systems Engineering*, *38*(3), 291-327. https://doi.org/10.1504/IJISE.2021.116245.

Tan, K. et al. (2023). Research on multi-objective optimal scheduling for power battery reverse supply chain. *Mathematics*, *11*(4), 1-26. https://doi.org/10.3390/math11040901.

Wang, C., Liu, J., Chen, Y., Liu, H., & Wang, Y. (2018). Towards in-baggage suspicious object detection using commodity wifi. In *2018 IEEE Conference on Communications and Network Security (CNS)*, Beijing, China, 30 May to 01 June. ttps://doi.org/10.1109/CNS.2018.8433142.

Wang, H. et al. (2024). Towards the next level of vehicle automation through cooperative driving: A roadmap from planning and control perspective. *IEEE Transactions on Intelligent Vehicles*. https://doi.org/10.1109/TIV.2024.3363873.

Xiaoping, B., & Meiyan, H. (2023). Reverse logistics planning research of building waste from perspective of closed supply chain in urban sustainable environment governance. *Science Progress*, *106*(1), 1-17. https://doi.org/10.1177/00368504231150427.

Xu, B. (2024). Precise path planning and trajectory tracking based on improved A-star algorithm. *Measurement and Control*, 1-13. https://doi.org/10.1177/00202940241228725.